Principles of formation of field crop rotations in the conditions of the forest-steppe of western Siberia

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Abstract. The article analyzes soil and climatic zoning of the territory of the forest-steppe of Western Siberia, population degree, contour of fields, biological economic features of crops, including the leading - spring wheat. The adaptive landscape approach to the zonal features of crop alternation was used in the work, which makes it possible to determine a reasonable ecological niche for each one, select crops in accordance with biological requirements, productivity, profitability of production, as much as possible to reduce repeated and monocrops. Monitoring of economic activity over the past 35 years has shown a tendency for commodity producers to be stratified by resource capabilities, technical equipment, and, above all, the level of agriculture intensification. In this regard, recommendations for optimizing field crop rotations are focused on expanding to 8-10 crops and adaptive varieties, considering their profitability and "soil improvement", limiting resowing, excluding continuous cultivation of agricultural crops. In conditions of limited intensive agriculture, about 5-10% of the arable land area belongs to crop rotations with winter, tilled crops, legumes, melilot, rapeseed, millet, clover, annual multicomponent grasses, the efficiency of which in terms of the yield of fodder units often surpasses grain-fallow crop rotations with short rotation. It is noted that in recent years, special attention has been paid to alternate crop rotations, which allow, with increase in farming standards and use of intensification means, to slightly reduce the fallow field and optimize the structure of arable land use, to increase the biodiversity of a set of crops and adaptive varieties. The tendency to switch to rotation crop, among commodity producers of a more humidified forest-steppe zone, is possible only with the use of fertilizers and the improvement of agrophytocenoses. The expansion of alternate crop rotations and the reduction of repeated sowing of spring wheat is also due to positive changes in hydrothermal conditions in arid soil and climatic zones of Western Siberia.

1 Introduction

To create crop rotations, it is important to determine the importance of agricultural crops as

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forecrop and their place in the formation of crop rotation schemes. Resowings are well maintained by corn, potatoes, pea oatmeal mixtures for green fodder, sunflower, pea, and wheat are much worse, barley and rye are better [1,2].

During the cultivation of agricultural crops in the southern forest-steppe, millet yield has decreased the most in 9 years (43.8%) compared to cultivation in crop rotation. The use of fertilizers and herbicides on monocrops did not allow increasing yields to the same level as in crop rotations, except for corn and annual grasses [3]. The corn yield increased by 13.3%, and the pea-oat mixture decreased by 2.1% compared to the productivity of these crops in the crop rotation. Only on millet, the effectiveness of fertilizers was low due to high contamination (44.8%), and herbicides did not provide an effect on oat, the contamination was (6%) [3,4]. When buckwheat was cultivated continuously for 3-5 years, its yield decreased compared to the productivity in the crop rotation by only 5%, and 8-10 years - already to 40.7%, barley - 4.7 and 37.5%, respectively, corn - 4.4 and 12.0%, wheat – 19.1-36.7%. Thus, buckwheat, pea-oat mixture, barley can be re-cultivated with an insignificant decrease in productivity, and corn with the introduction of fertilizers and herbicides – even continuously. Wheat, sunflower for silage and oil, millet do not tolerate resowing [5,6].

The purpose of the study is a technological assessment of the impact of alternating crops for the formation of field crop rotations in the forest-steppe of Western Siberia.

2 Objects and methods of research

The experiments were carried out in the southern forest-steppe zone of the Omsk region in long stationary crop rotations in 1984-2019. Since 2010, the schemes of crop rotations of stations have been modernized by introducing technical crops (rapeseed and soybeans) into them. That allowed to increase the variability in the formation of crop rotation schemes. The placement of plots is randomized into four tiers, the size of plots is 50×25 m and 50×12.5 m. Varieties of field crops in the experiment, zoned for Western Siberia: spring wheat – "Omskaya 36", barley – "Omskiy 95", soy – "Zolotistaya", rapeseed – "Jubileyniy", oat – "Irtysh 21", corn – "Omka 135". The soil of the experimental site is meadow-chernozem with a humus content of up to 7-8%.

Meteorological conditions were close to the average long-term, with HTC of 1.04. The driest weather conditions according to the HTC were observed in 2004. (0.67); 2008 (0.69); 2010 (0.55); 2012 (0.69); 2014 (0.68). Statistical processing in the experiments was carried out by the method of variance analysis according to B.A. Dospekhov [7]. The system of agrotechnical measures was built considering the recommendations of the "Omskiy ASC" for the forest-steppe zone of Western Siberia [8]. The assessment of economic and agrotechnical measures and crop rotations was carried out according to the methodological recommendations of the Siberian branch of VASHNIL (the All-Union Academy of Agricultural Sciences) [9].

3 Results and Discussion

It is determined that in the conditions of the forest-steppe of Western Siberia, the instability of yield for grain crops is characteristic, especially after non-fallow forecrops (Table 1).

Table 1. Dynamics of spring wheat productivity in the forest-steppe of Western Siberia, 1984-2019

Indicator	Wheat for fallow		Wheat for wheat		Continuous wheat	
	number of cases	%	number of cases	%	number of cases	%
Number of years of records, including productivity, t/ha	35	100	35	100	35	100
>3.0	4	7.1	-	-	-	-
2.5 – 3.0	7	12.5	2	3.6	-	-
2.01 – 2.5	18	35.7	10	26.8	4	11.1
1.01 – 2.0	10	32.2	14	42.9	20	55.6
0.51 – 1.0	7	12.5	6	19.6	9	25.0
<0.5	-	-	4	7.1	3	8.3
Average yield for 1984 – 2019 t/ha	2.36		1.69		1.35	

Long-term studies have established that for pure fallow, wheat yield above 2.0 t/ha was in 35.7% of cases, with repeated sowing - 26.8 and monosowing – 11.1%.

In the forest-steppe, the optimal field crop rotation is assigned to a greater extent an increase in the fertility of zonal soils and hydrological role. Several scientists [5,10,11] note the positive moisture accumulation effect of dead, seed, and green-manured fallow. They assign a special place to coulisse fallows and other moisture-accumulating measures (snow retention, leveling of arable land, mulching, post-sowing rolling, and others), which is important for the forest-steppe, since the amount of precipitation during the growing season is less than 380 mm, and the hydrothermal coefficient in the zone is only 0.8-1.0.

When placing spring wheat after peas, corn on silage, the third crop for fallow after various forecrops, crop yields differed significantly (Table 2).

Table 2. Formation of crop yield depending on forecrop, 35 years, in tons per hectare.

Forecrop	Crop		
	spring wheat	pea	corn
Wheat	1.36	1.81	34.12
Barley	1.80	1.67	35.40
Oat	1.60	1.56	31.73
Buckwheat	1.93	1.72	32.70
Pea	2.26	1.59	36.48
Millet	1.99	1.91	34.39
Sunflower for silage	2.05	1.65	36.66
Corn for silage	2.09	1.89	33.23
Pea-oat for green fodder	1.94	1.93	38.14
Continuous cultivation	1.34	1.18	32.88
LSD_{05}	0.34	0.19	2.09

Studies show that acceptable forecrops for spring wheat can be, in addition to corn and pea-oat, peas, sunflower for silage, buckwheat, millet, and barley, which provide an increase in yield compared to continuous wheat, from 0.24 to 0.92 t/ha, satisfactory – oat. It was revealed that all grain crops for spring wheat are better forecrop than wheat.

Good forecrops in the forest-steppe zone for pea: pea-oat for green fodder, millet, corn for silage, wheat, when placed on which the pea yield is higher compared to its permanent cultivation by 0.63-0.75 t/ha; then there are such precursors as buckwheat, barley, sunflower for silage, and pea and oat forecrops were not inferior being within the experimental error. Pea, when placed on good forecrop in equal conditions with wheat, is

slightly inferior to it by yield.

According to the results of field experiments, it was found that barley productivity, depending on the forecrop, varied from 1.41 to 2.16 t/ha, and oat – from 1.49 to 1.98 t/ha, that is, barley was more responsive to the effect of the forecrop. In barley, in relation to monocrop, the increase in yield, depending on the forecrop, varied from 0.7 to 53.2%, then oat - from 10.1 to 32.9%. The lower yield of oat compared to barley is obtained because in some years of observations the oat was severely damaged by leech. Over a fairly long period of observations (1985-2015), the yield of oat was 2.35, and barley - 2.07 t/ha.

According to the results of stationary field studies, it was found that the lowest yield of spring rapeseed was obtained from forecrops from the cruciferous family. The best forecrop for it in the forest-steppe is dead fallow, annual grasses are good, especially those sown in early (May) and late (July) terms, and grain crops are satisfactory. Even though for all forecrops rapeseed oil seeds were inferior in yield to wheat, protein yield per unit area increased.

Experiments conducted in our country and abroad have established that even with intensive use of chemicals, with a general level of increase in productivity of field crops, the value of crop rotations does not decrease, but increases. With intensification, the role of forecrops changes somewhat: those that were considered bad, with a high level of agricultural technology, improve qualitatively, and the possibility of expanding the composition of forecrops and variants of fruit-bearing alternations allows to specialize crop rotations [3,5,10,11].

It was revealed that in the forest-steppe of Western Siberia, the effectiveness of crop rotation is 25-72%, and chemicalization is 31-43% (Table 3).

Table3. Productivity of crops in field crop rotations of forest-steppe, grain units, 1984-2019, tons per hectare.

Placement of crops	Variant	Yield	Increase, % of	
			chemicalization	forecrop
Annual grasses	With chemicalization	1.94	34.7	-
	Without chemicalization	1.44	-	-
1st wheat after annual grasses	With chemicalization	2.51	31.4	39.4
	Without chemicalization	1.91	-	-
2nd wheat after annual grasses	With chemicalization	2.26	43.0	25.0
	Without chemicalization	1.58	-	-
Grain-fodder	With chemicalization	2.35	39.9	30.6
	Without chemicalization	1.68	-	-
Average for crop rotation	*With chemicalization*	*2.26*	*37.0*	*25.6*
	Without chemicalization	*1.65*	-	-
Wheat for fallow	With chemicalization	3.09	-	71.7
2nd wheat after fallow	With chemicalization	2.56	-	42.2
Pea	With chemicalization	1.94	-	7.8
Wheat after pea	With chemicalization	2.32	-	28.9
Average for crop rotation	*With chemicalization*	*2.48*	-	*37.8*
Continuous wheat	With chemicalization	1.80	-	-

It should be noted that the productivity of the five-course grain-fallow crop rotation increases by 37.7% compared to continuous wheat, and the four-field grain-fallow with seed fallow - by 25.6%.

The effectiveness of chemicalization agents in the four-course field grain-fallow crop rotation increases by 37.0%, or by 0.61 t/ha, and the payback of fertilizers reaches 10.2 kg.

Due to the increase in the level of grain production intensification, the expediency of reducing the area of the fallow field in the structure of arable land increases, the need for fruit-bearing crop rotations increases. Therefore, we have developed a technological system for cultivating the main crop in the region – spring wheat, of various intensity levels (Table 4).

Table 4. Technological system of spring wheat cultivation on chernozem soils of the forest-steppe of Western Siberia.

Elements and technological operations	Level of intensification		
	extensive (60-70%)*	semi-intensive (20-30%)*	intensive (5-10%)*
Planned grain yield, t/ha	1.6-2.0	2.0-2.5	2.5-3.0 and more
Grain yield from 1 ha of arable land, t/ha	1.3-1.7	1.7-2.1	2.2-2.7 and more
Gluten content in grain, %	20-24	24-26	26-27
Share of fallow in arable land structure, %	16-18	12-16	less than 12
Tillage system in crop rotations	single-furrow. combined	combined. minimal	minimal. No-Till
Means of intensification	herbicides	herbicides + fertilizers (N20-30 kg/ha r.a.)	herbicides +fertilizers (N30-45 kg/ha r.a., P 15-20 kg/ha r.a.) + fungicides + N-top dressing

**Percentage of farms operating at this level of intensification*

4 Conclusions

In long-term stationary experiments, it was found that the unsystematic placement of crops in the crop rotations of the region leads to a deterioration in the fertility of zonal soils, which ultimately leads to a decrease in the productivity of arable land.

Increase if efficiency of the use of soil and climatic resources of yield region and biopotential of grain crops is impossible without a rational structure of arable land use with zonal soil and climatic features.

The reduction of repeated and monocrops, due to the rational selection of forecrops, the formation of scientifically based field crop rotations and optimization of the structure of arable land use, will allow in the future to increase the gross harvest of high-quality grain in the region, stabilize and increase soil fertility, improve the phytosanitary condition of crops, increase the productivity of grain production.

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